

STAINLESS STEELS.

*Paper presented to the Institution, Sheffield Section, by
Dr. W. H. Hatfield, F.R.S.*

MR. President and Gentlemen, I greatly appreciate the honour of being invited to speak to you this evening on stainless steels. The subject is a very wide one, but I shall endeavour to deal with those phases of the subject which are likely to be of special interest to production engineers.

In the first place, I think it is of interest to place the exhibits, which you see round the room, before you, because nothing is so convincing of the utility of the metal as a practical demonstration. An examination of these various products will show at once the vast range of technique which is employed in the application of these steels.

In the year 1914, Dr. Walter Rosenhain published his book, "The Introduction to Physical Metallurgy," one of the most important books on the subject that was ever written, and I was much interested the other night in finding the following sentence in this book. After discussing in a very interesting manner the various theories which had been advanced relative to the corrosion of iron and steel, he said: "Whichever of these rival views should ultimately prove correct, the prospect of producing a cheap form of iron and steel which shall be practically incorrodible is extremely remote." That was the view entertained in 1914 by one of our leading metallurgists, and I venture to say that none of his fellow investigators would have quarrelled with that view. It is not for me as a scientific man to deal with the economic aspect of rustless steel to the Institution of Production Engineers, but disregard of this aspect would, I think, be a disadvantage.

Since 1914, great strides have been made. Here is a tray made of the austenitic rustless steel, and here a rustless knife. In these two articles are represented the two essential types of rustless steels; in the knife is an example of a cutting article fabricated from the martensitic rustless steel, that is a steel representative of the 13% chromium class, which, when heated to a high temperature, will harden and, by subsequent light tempering, can be left in such a condition that it has the hardness of a cutting implement and the tensile strength of a high alloy steel. On the other hand, the tray represents the type of finished product which can be fabricated from the austenitic chromium-nickel steel, that is a steel with a higher

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chromium content to which nickel has been added and which, in its normal condition, is extremely soft and plastic. The addition of 18% chromium and 8% nickel confers upon the steel a resistance to corrosion of the same order as that of the noble metals. The tray which you see has been in my own dining room some seven or eight years. It has never been cleaned, and therefore that surface which is before you to-night is a permanent surface produced by composition plus thermal treatment, with which I propose to deal later.

We have before us, therefore, stainless steels of two types, the hardening type and the soft type, whilst intermediate between these two varieties are a number of rustless steels of varying composition from which can be obtained mechanical properties of such an order as to make them fitted for any conceivable purpose.

Some three or four years ago, on the occasion of the Faraday Centenary, I was one of the six people representing the world of chemistry who were invited by the B.B.C. to broadcast from Savoy Hill. I took as my subject "The Corrosion of Steel." Having submitted my manuscript for censorship, I received a wire asking me to call the next time I was in town. It transpired that the censor had taken exception to a certain paragraph, in which, using artistic licence, I had said that owing to the researches on the influence of chromium and chromium-nickel in producing rustless steels it would now be possible to produce a rustless battle-fleet and so diverse were the properties of rustless steel that the whole of a ship could be built of it. I had then remarked how glorious it would be to see a bright battle squadron sailing the seven seas. I had of course drawn this somewhat imaginative picture merely to emphasise to my hearers the fact that rustless steel can now be obtained in every conceivable form, but I was asked by the censor to eliminate the paragraph in question on the ground that it was "propaganda in favour of armaments."

To return to my scientific friend's reference to a "cheap form of iron and steel," I do not like to read such a phrase: "cheap" and "dear" are not terms with which the scientific world should deal, but I would like to refer briefly to this aspect, since production engineers must take into consideration the final cost of the product, whatever that product may be.

Some three or four years ago I gave to one of my friends, an engineer admiral, a stainless pocket knife, the scales and blades of which were both made of stainless steel. He was very delighted with it, but on meeting some six months afterwards, he intimated that if we desired stainless steels to be a commercial success they would have to be put on a much cheaper basis. He so liked the stainless knife I had given him that he had written to the cutlery,



Fig. 1.—"Staybrite" Steel Tray.

whose name and address were on the blade, asking them to send him half a dozen similar knives. The knives arrived and the bill came with them. It appeared that the firm had charged 5s. 6d. each for the knives, which cost he considered excessive. I asked if he happened to have the knife with him and, such being the case, we proceeded to make an investigation. Together, we weighed the knife on a delicate balance and, after making a few calculations the actual cost of the steel in the 5s. 6d. pocket knife was found to be 1½d. Now, gentlemen as production engineers, you will appreciate that the effort in labour, plant, and overheads, which go to constitute the ultimate costs of the finished article are abnormal in relation to the initial price of the raw material. The steel only cost 1½d. and that causes me to make a rather astonishing statement. Research and production methods have resulted in the manufacture of this new material at a price considerably lower than that of the old material, giving at the same time greatly enhanced properties. Before stainless knives came into vogue, table cutlery was made from ordinary carbon shear steel, a steel which stained when placed in contact with vinegar, fruit juice or corroding media of any description, whilst pocket knives were made from crucible cast steel, a carbon steel which stained very badly. To-day stainless steel is supplied to the cutlery manufacturers at a price very much lower than that paid for the old shear steel. The results of scientific research and investigation have placed on the market a most valuable material, stainless steel, which has revived the cutlery trade of this city. This is a very great technical advance and an achievement of which the City of Sheffield may well be proud.

I think it will be agreed that this tray (Fig. 1) is a thing of beauty. Had the same article been made of silver the metal would have cost in the region of £5,000 per ton, whilst the price of the material of which the tray is made is under £200 per ton. There again is a great achievement. Such a material is worthy of the art and ingenuity of the craftsmen of Sheffield and other industrial cities for the production of beautiful things for the household. A delightful appearance and permanent surface may be obtained at a cost which is drastically lower than any material previously associated with such articles.

The foregoing remarks will perhaps give the impression that these steels are of interest only to the cutlery manufacturers and silver-smiths of Sheffield. This is very far from being the case as the following analysis of the application to which both the austenitic and martensitic steels have been put over the last twelve months will show. Here is a detailed quantitative survey indicating the relative proportions in which the different industries have absorbed this new steel :—

STAINLESS STEELS

INDUSTRIAL APPLICATIONS OF STAINLESS AND "STAYBRITE" STEELS IN 1934

Industry	Total Production %		Different Sections of the Industry	Typical Items of Application
	Stain- less Steels	"Stay- brite" Steels		
AIRCRAFT ...	15	4	—	{ Exhaust manifolds, valves, petrol and oil piping, spars, ribs, struts, undercarriage frames, hull plating, eye bolts, rigging screws.
ARCHITECTURAL FITTINGS ...	—	6.5	—	{ Shop fronts, mouldings, hand-rails, counters, grills, ventilators, signs, general fittings for outside and inside, ornamental work.
CHEMICAL ...	1	5.25	General chemical plant ...	{ Reaction vessels, mixers, condensers, evaporators, storage vessels, transport tanks and drums, pumps, autoclaves, valves, steam-jacketed pans, pipe lines, heating coils.
			Glass industry ...	{ Moulds, rabbles.
			Oil industry ...	{ Pumps, valves, pipes, cracking stills.
			Paper industry ...	{ Beater bars, refiner bars, valves, pumps, digester parts, sheets and plates for glazing mill board and card board, filter screens.
			Photography ...	{ Tanks, trays and dishes for developing and fixing, clips, glazing drums, camera parts.
			Rubber ...	{ Moulds, mandril bars for production of rubber hose, latex holding tanks.
ENGINEERING ...	58	31.5	Soap ...	{ Moulds, press plates, pumps, filter plates.
			Automobile ...	{ Valves, water pump spindles, carburettor parts, all bright parts, e.g., radiator shells, windcreens, lamps, handles, wheels, moulding.
			Electrical ...	{ Resistances, switch gear equipment, shafts, general equipment for electric power plant.
			Steam turbine ...	{ Turbine blading and shrouding strip.
			Water turbine ...	{ Pelton buckets, wheels, runners, impellers, valves.
			Telephone ...	{ Finger dials, small coil springs, and spindles in automatic selector arrangement.

THE INSTITUTION OF PRODUCTION ENGINEERS

Industry	Total Production %		Different Sections of the Industry	Typical Items of Application
	Stainless Steels	"Stay-brite" Steels		
ENGINEERING ...	58	31.5	Mechanical, steam and hydraulic...	Pumps, shafts, impellers, valves, pipes, springs, meter parts, jets and nozzles, refrigerating plant, weighing apparatus, wire, gauze and rope, dredger parts.
			Civil or municipal	Road studs, signs.
			Marine ...	Steam and hydraulic valves, pumps, shafts, propellers, springs, bright parts, e.g., cabin fittings, deck fittings, and general ship's fittings.
			Mining ...	Pumps and spindles, wire rope, valves, coal washing screens, conduits, ventilation plant.
FOOD AND ALLIED INDUSTRIES	---	6.25	Dairy ...	Milk storage vessels, coolers, pasteurisers, condensers, transport tanks, cream and cheese plant, general utensils.
			Brewery ...	Storage vessels, fermenting vessels, pumps, pipe lines, mash tun covers, yeast trolleys, hop backs.
			Food manufacturing	Boiling pans, mixers, evaporating pans, ladles, general utensils.
			Restaurant engineering	Hot plates, table tops, sinks, bain maries, grilles, soda fountains, bar equipment.
HOUSEHOLD AND DOMESTIC ...	21	10	Table-ware ...	Cutlery, spoons, and forks.
			Domestic utensils and Hollow-ware	Saucepans, bowls, trays, casseroles, cans and jugs, door fittings, bathroom fittings, hearth furniture, name plates.
TEXTILE AND DYEING	---	3.5	Textile ...	Parts of looms, knitting machines, wool washing and scouring plant, laundry washing and dry cleaning plant, plant for artificial silk manufacture.
			Dyeing ...	Complete dyeing machines, dye-vat linings, rollers, winches, pumps, steaming rolls, heating coils.

The balance of the 100% of the stainless steel and "Staybrite" steel production is taken up by a variety of other industries, not mentioned in detail as above, but the above list will be indicative of the directions in which these steels are being used.

STAINLESS STEELS

A study of this analysis will show that there is hardly an industry in this country which has not used these steels.

In the motor industry, for example, "Staybrite" steel is finding application for the bright parts of cars such as radiators, lamps, and windcreens. Chromium plating, the alternative to the use of

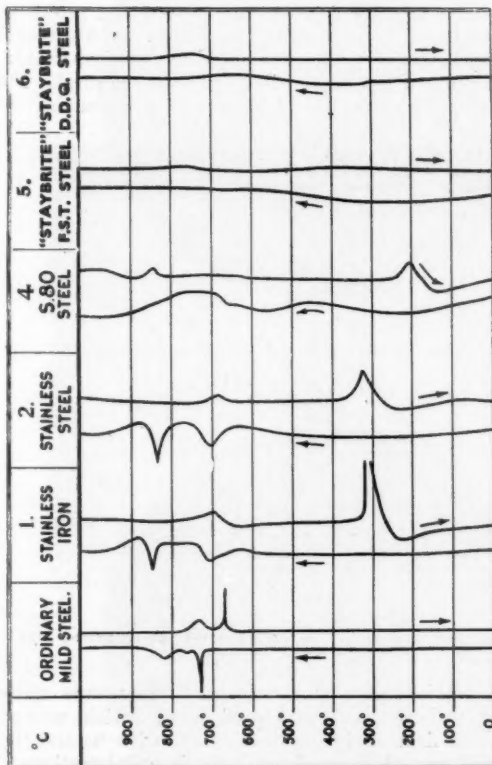


Fig. 2.
Heating and cooling curves of various types of stainless steel as compared with ordinary mild steel.

[Much is to be gained in the manipulation of this class of steel by a full appreciation of the nature of the critical points of the different types. The martensitic steels have well marked "carbide" change points (see 1 and 2) indicative of the necessity for the high hardening temperature. These changes are indeterminate in 4 whilst in the austenitic steels (5 and 6) these critical points do not occur and hence the austenitic or "solid solution" character of the steels.

"Staybrite," carries great conviction for the first few months, but very soon the chromium tends to peel off leaving the underlying metal exposed. Rusting then occurs and the whole thing looks unseemly. That, at least has been my experience with a new car I had as recently as May. Had these parts been made, as in fact they are in certain makes of cars, of the austenitic stainless steel, no such

trouble would have been encountered, and I look for a great extension in the use of these steels in the automobile industry, not only from the point of view of the bright parts, but also for those parts which are subject to high stresses and corrosion, as for example pump spindles.

During the course of the development of the austenitic "Staybrite" class of material there have been some very interesting problems. The original "Staybrite" contained 18% chromium and 8% nickel, and in the early days, one of our local firms of silversmiths decided to try the manufacture of spoons and forks of such material. The steel was supplied and the spoons and forks were duly made. So

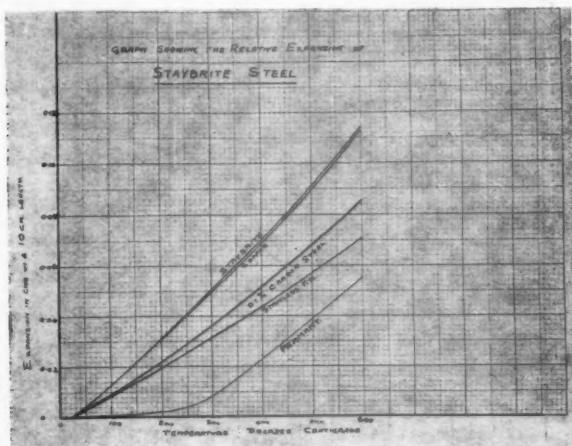


Fig. 3.
Relative expansion of Stainless and "Staybrite" steels as compared with copper, mild steel, and "Permant."

far as technical achievement was concerned, they were quite successful but the ultimate cost of the finished article proved to be too high. The firm again got into touch with us and the whole matter was discussed between us. It is collaboration of this type which is so essential in the technical development of the subject. To produce the spoon from the 18/8 material some nine operations of manipulation (cold-working and annealing were found necessary, and the selling price did not warrant these nine operations. We in our research laboratories had already investigated many alloys which we had not seen fit to suggest were of immediate commercial importance. Since, however, the necessity

STAINLESS STEELS

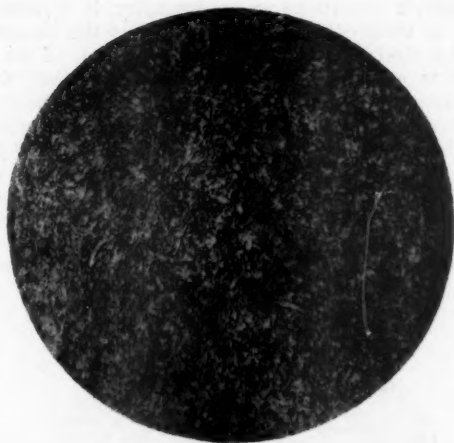


Fig. 4.

13% Chromium steel. Oil-hardened 980°C., tempered 750°C. ($\times 200$).



Fig. 5.

13% Chromium steel. Oil-hardened 960°C., tempered 180°C. (Cutlery Temper). ($\times 200$).

for these multiple operations was a disability, it appeared possible that certain of these other alloys might meet the situation better than the 18/8 steel. After careful consideration of the available research data we came to the conclusion that one of the "Staybrite" alloys containing 12% chromium, and 12% nickel, which on softening from a temperature of 1,050°C. had a Brinell hardness of 130 as against a Brinell hardness of 160 for 18/8 material, might prove suitable for the production of spoons and forks. A portion of our experimental material was therefore sent on to our friends, and it was found that by this modification of composition from 18/8 to 12/12 the nine fabricating processes could be reduced to five. The commercial significance of this fact was obvious. This was some six or

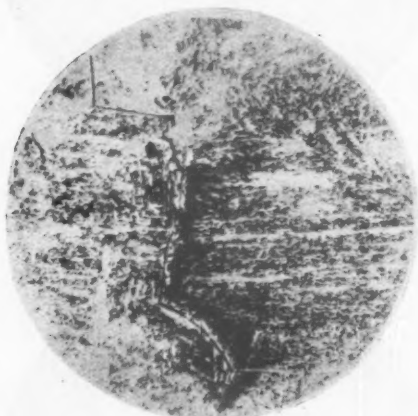


Fig. 6.

13% Chromium steel (overheated). ($\times 250$)

seven years ago; almost immediately concentrated efforts were put upon that material and "Staybrite" D.D.Q. (Deep Drawing Quality) steel came into its own. Spoons and forks of rustless steel found their way on to the market in that way. That case of direct contact between the manufacturers and the research laboratories is quoted merely to emphasise the point that if it so happens that none of the present varieties of rustless steel fall exactly into line with your own particular requirements it may well be possible that amongst our research alloys there is something which will foot the bill.

I do not want to suggest to the manufacturer of the ordinary commercial steels that rustless steel is likely to replace steels in

STAINLESS STEELS



Fig. 7.
Austenitic chromium nickel steel. As cast. ($\times 200$).



Fig. 8.
Austenitic chromium nickel steel casting (annealed). ($\times 200$).

general. According to the latest analysis the content of the earth's crust as regards chromium is 0.038%, whilst the iron content of the earth's crust is 5.5%. Therefore, a moment's consideration will make it quite clear that there is not the least possible chance of making all steel rustless. In other words the rustless steels must remain a special product. Nevertheless, from what I have said regarding the economic aspect of the matter it will be gathered that the prices at which rustless steels are marketed are below the values which would be deduced from the extreme rarity of the principal alloying metal.



Fig. 9.

Austenitic chromium nickel steel. (Rolled bar, A.C. 1150°C.). ($\times 200$).

Considerable controversy has arisen from time to time regarding the origin of the stainless steels. Therefore, to-night, I propose to lay before you the historical facts.

In 1766, J. G. Lehmann¹ described a new mineral which he had obtained from Siberia. This is now known as crocoite, a natural form of lead chromate, but the composition remained unknown until, in 1797, L. N. Vauquelin² showed that the contained lead was united to the oxide of a new metal to which he applied the name "chrom," from the Greek "chroma"—colour. The metal was at that time, however, regarded merely as of scientific interest and it was

¹ Nov. Comm. Acad., Petrop, 1766, 12, 256.

² Ann. Chim. Phys., 1798 (1), 25, 21, 194.

STAINLESS STEELS

many years before chromium became a really serious element in the world's economy.

The first record of the use of chromium as an alloying element with iron is contained in Stodart and Faraday's account of their experiments on the "Alloying of Different Metals with Steel," published in 1820³. In 1872, Woods and Clark⁴ took out a patent for the addition of chromium to iron and steel. They claimed that, by the addition of chromium or tungsten, iron or steel are rendered "less subject to rust or oxidation," and the toughness of the iron or temper of the steel are very materially improved." The ultimate composition of the steel is somewhat doubtful but may be judged

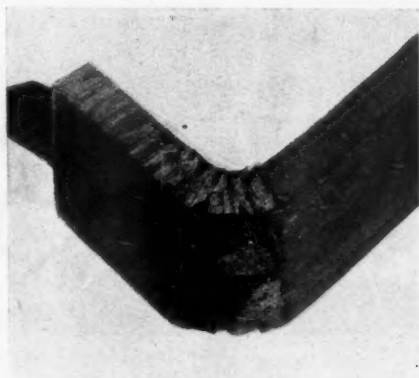


Fig. 10.

Standard intercrystalline corrosion test.

to be between 20-30% chromium with just a small percentage of carbon. It was also claimed that such material would be useful for outlery coming into contact with acid. These claims, however, remained unnoticed, chromium being still such a rare element, the invention was considered as only of academic interest.

In 1892, Sir Robert Hadfield⁵ published a valuable series of experiments on the influence of chromium on steel, the chromium content of the steels ranging from 0.22-16.47%. In conducting his corrosion experiments, however, he did not use nitric acid and, therefore, it may be considered unfortunate that he omitted those critical tests which would have disclosed the peculiar characteristics

³ Phil. Trans. Roy. Soc., 1822, 112, 253.

⁴ British Patent, No. 1923, 1872.

⁵ J. Iron and Steel Inst., 1892, No. 2, pp. 49-114.

of the alloys which he had produced. A few years later, an important paper was given by Guillet⁶ in which the mechanical properties of steels containing up to 20% of chromium were discussed, but he also failed to recognise the corrosion resisting properties of these alloys. It remained for P. Monnartz⁷ in the year 1911, to publish the results of his investigations into the resistance of iron-chromium alloys to acid attack. He found that an increase of the chromium content from 4.14% was accompanied by a very marked and rapid increase in the resistance of the steel to attack by dilute nitric acid, the corrosion resistance being still further improved in proportion as the chromium percentage was increased. This, however, was

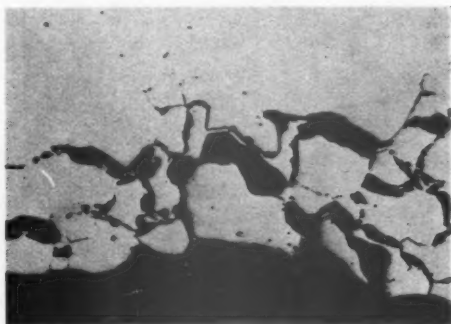


Fig. 11.

Example of intercrystalline corrosion in liquor containing sulphurous acid used in cellulose manufacture (unetched).

again regarded purely as an academic discovery and was entirely ignored by the industrial world.

Such was the position when, in 1912, one of the directors of my company wrote to Mr. Brearley suggesting that chromium steel would probably be found very suitable for rifle barrels and, on October 9th, Mr. Brearley replied, agreeing with this suggestion and making a number of observations with the object of extending the idea. A further letter from Mr. Brearley (dated July 7th, 1913) specified the composition of an electric furnace cast which he would like making—up to 0.30% carbon and 10-15% chromium. A steel, according to this specification was cast on August 20th, 1913, the analysis showing: carbon 0.24% and chromium 12.86%. During the course of his investigations Mr. Brearley noticed that this steel

⁶ *Revue de Metallurgie*, 1904, pp. 155-183.

⁷ *Metallurgie*, Vol. 8, pp. 161-176, 193-201.

STAINLESS STEELS

did not rust when exposed for considerable periods to the atmosphere of the laboratory. Moreover, it was observed that the reaction of the same steel to etching reagents varied according to the con-

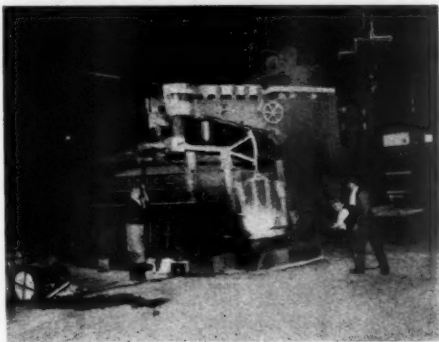


Fig. 12.

Electric melting furnace—from stage (capacity 30 tons).

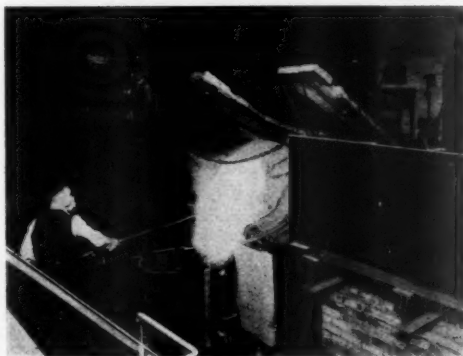


Fig. 13.

High frequency furnace—tapping (capacity 1 ton).

dition of heat-treatment. Mr. Brearley quickly realised the possibilities of such a corrosion-resistant material in which the requisite hardness for cutlery could be obtained. On his own initiative he persuaded a cutlery firm to make knives from this material: they

THE INSTITUTION OF PRODUCTION ENGINEERS

were successful and that was the beginning of the stainless and rustless steel industry in this city.



Fig. 14.

Teeming stainless steel from ladle into ingot moulds.

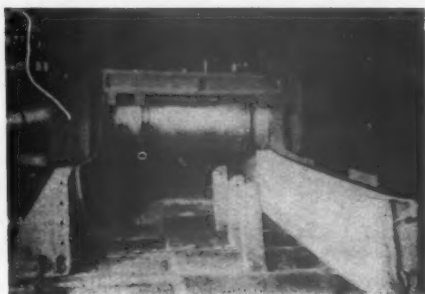


Fig. 15.

Rolling.

In 1914, Mr. Brearley left our company, and it fell to me to succeed him and I, with the support of a brilliant group of investigators, took up the development from this point. We in-

STAINLESS STEELS

vestigated the higher chromium steels and added nickel, eventually arriving at the austenitic steels.

Concurrently with our own investigations, the Krupp Research Laboratories in Essen were also experimenting on similar lines



Fig. 16.

32 in. hot rolling finishing mills.



Fig. 17.

Polished "Staybrite" steel warehouse.

with the result that the Directorates of the two companies came to the conclusion that we could usefully pool our knowledge, thereby greatly benefiting the development. Such is the position to-day.

THE INSTITUTION OF PRODUCTION ENGINEERS

I should here like to take the opportunity of referring to a letter which appeared in the *Daily Telegraph* in which the writer stated that austenitic chromium-nickel steel had been used for lining inner tubes of German guns. This is quite untrue; the material is totally unsuitable. The next assertion, that the composition

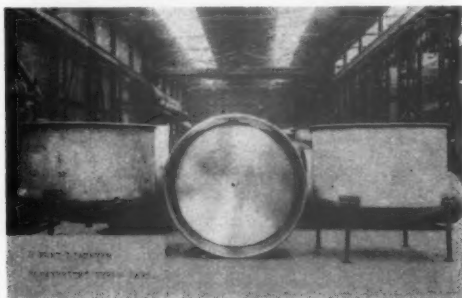


Fig. 18.
"Staybrite" steel syrup-pan (6ft. diameter).

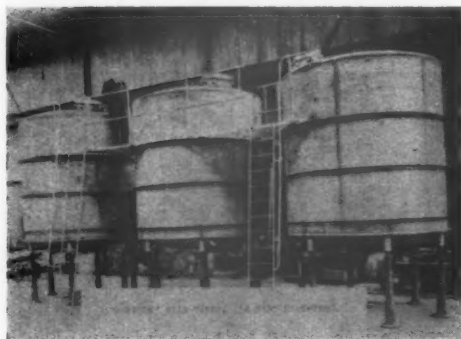


Fig. 19.
"Staybrite" steel milk tanks (8 ft. diameter).

of the material now being produced in this country, samples of which you have examined to-night, was of German origin, is equally ridiculous and without foundation.

The rustless steel as you know it to-day, whether it be the stainless steel used for knives, or the austenitic steel, is indeed an indigenous

STAINLESS STEELS

local development and can rank along with silver plate and Huntsman's crucible steel, as a result of local effort.

In the steels which we are considering to-night, we have of course particular compositions but it is amazing to consider the possible variations which could be obtained using only the ordinary alloying elements which are commonly found in engineering and similar steels. If the possibilities of the fourteen or fifteen alloying elements, with iron as the base material, were explored, even if each element were varied only three times, something like three hundred million alloys would have to be made. In our research laboratories we have made something like 1,100 of those possible millions of variations so you will appreciate there is a great deal still to be done. The subject is immense.

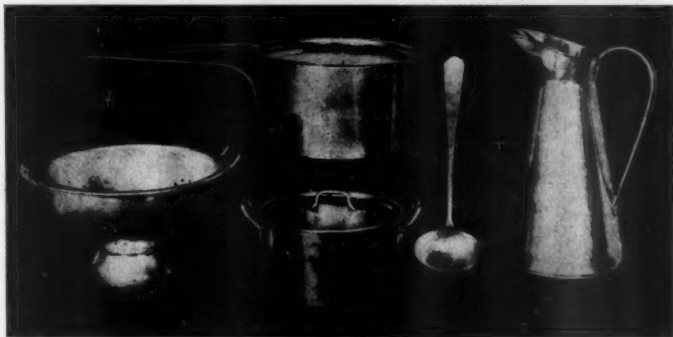


Fig. 20.
Hollow-ware in "Staybrite" steel.

The question as to why rustless steel is rustless often arises and I think it can be most clearly explained by saying that the high percentage of chromium in the steel is responsible for the spontaneous production on the surface of the metal of an oxygen containing layer which prevents further oxidation. In view of the brightness of the material this may seem strange, but it is surmised that this layer is only a few molecules thick and it would need to be at least thirty molecules thick before it became noticeable.

You may ask what evidence we have regarding the existence of this oxygen containing layer. Induced passivity was observed by J. Keir⁸ as long ago as 1790, in so far as he had remarked that iron, after treatment with concentrated nitric acid was no longer attacked

⁸ Phil. Trans. Roy. Soc., 1790, Vol. 80, p. 359.

by dilute nitric acid, the passive iron losing its peculiar property on drying or on being kept in water. In 1836, the great Michael Faraday⁹ gave what proved to be the true explanation of such passivity. He visualised that "the surface of the iron is oxidised or the superficial particles of the metal are in such relation to the oxygen of the electrolyte as to be equivalent to oxidation." It was, however, nearly a hundred years later that my friend Dr. U. R. Evans¹⁰ of Cambridge demonstrated the existence of such a film

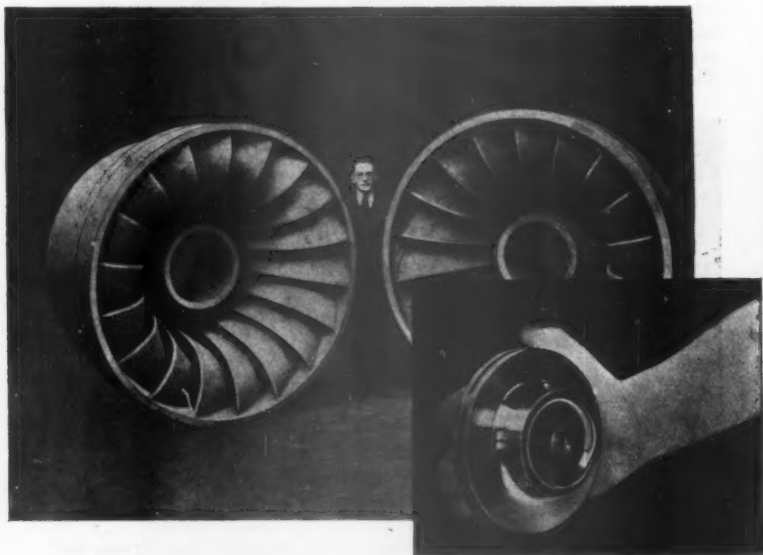


Fig. 21.

Water turbine runners in stainless steel.

by actually isolating it. Shortly after this achievement I went down to Cambridge and there actually saw this film under the microscope. The polishing marks of the outer surface of the metal were definitely to be seen on the gossamer-like patches of film which were floating under the objective. "Are they actually oxide of iron?" I asked, and Evans promptly added a drop of ferro-cyanide which immediately produced the well known prussian blue colouration.

⁹ Phil. Mag., 1836 (3), Vol. 9, p. 53.

¹⁰ J. Chem. Soc., 1927, p. 1020.

STAINLESS STEELS

After Dr. Evans had isolated the passive film on ordinary iron, it was a very short step to deduce that the presence of chromium in the stainless steel facilitated the instantaneous production of an oxide layer, thus developing a film which was at once much nearer perfection and more durable than any which could be induced on pure iron. Thus, the passive film which is responsible for the resistance of the metal is essentially due to the composition of the metal itself.

As regards the chemical industry, and industries in which these materials are used because of their non-corrosive properties, the



Fig. 22.
Pelton buckets in stainless steel.

initial passive film may be in itself modified by the local conditions of usage which are to be encountered. The particular corroding medium enters into this matter and a modified type of passive film results which in some cases may function for the purpose of preventing further attack. An interesting example of this phenomenon was encountered some years ago in connection with resistance to certain acid solutions of ammonium sulphate. Samples of the austenitic rustless steels were tested out in service in the acid ammonium sulphate solutions in question. The tests appeared satisfactory and an order followed for the requisite steel. To the

dismay of the engineers and ourselves, when the plant was put into operation it was found that the rustless steel was attacked. A thorough investigation followed : It was found that this ammonium sulphate solution did actually attack the austenitic stainless steel. Some five to six weeks later we again discussed the matter, and decided to do the tests again. The tests were done again on the original samples and we found on the second set of experiments that the steel was not attacked by the ammonium sulphate. Both sets of tests had been properly conducted ; the question was to find out the cause of the difference. Arising from that experience I communicated with the engineer in charge of the plant, which had been closed down as unsatisfactory, and told him I thought that if he



Fig. 23.

Chemical plant in "Staybrite" steel.

started the plant up again it would be all right. He was rather amazed, but agreed to follow my advice, with the result that everything was satisfactory and there was no further trouble. Clearly from that somewhat empirical experience it is obvious that the ammonium sulphate solution must have come into play in rendering the material resistant, and so it has been found with other reagents.

Apart from the intrinsic properties, a most important factor is perfection of surface, and in the manufacture of rustless steels obviously, special attention must be given to the production of the surface. In the case of rolled black sheets of ordinary steel the surface of the steel is oxide, i.e., scale rolled on. It has a nice blue planished appearance but it is scale, nevertheless, and if you were to endeavour to remove that scale even most carefully in the laboratory, an irregular surface consisting of hills and dales would be

STAINLESS STEELS

presented. In the technique of rustless steel production the initial manufacture and subsequent procedure must be such that the actual surface is as near perfection as possible.

I have already referred to the fact that some of the early investigators, who actually made chromium steels, failed to discover the characteristics which we associate with those materials to-day. The method then in general use was that of immersion in sulphuric or hydrochloric acid which our present knowledge shows could not have led to the epoch making discovery of chromium rustless steels.

Table 1 shows the corrosion resistance of three low carbon chromium steels, containing 10, 13, and 16% chromium, respectively, to

TABLE 1

CORROSION TESTS ON LOW CARBON CHROMIUM STEELS						
(Loss in grams/sq. cm.)						
C %	Si %	Cr %	Brinell Hardness Number	Hydrochloric Acid, Concentrated	Nitric Acid, Sp. Gr. 1.20	Sulphuric Acid, 10%
0.08	0.56	10.08	230	0.0148	nil.	0.0722
0.07	0.73	13.26	185	0.0297	nil.	0.2027
0.07	0.77	15.96	141	0.0416	nil.	0.2763

hydrochloric, sulphuric and nitric acids. It will be seen that the presence of chromium gives no protection against sulphuric or hydrochloric acid; on the contrary, the steel becomes more readily soluble as the chromium increases.

TABLE 2

CORROSION TESTS ON "PURE" METALS			
(Loss in grams/sq. cm.)			
Metal	Hydrochloric Acid, Concentrated	Sulphuric Acid, 10%	Nitric Acid, Sp. Gr. 1.20
Iron... ..	0.0814	0.0327	0.7165
Nickel	0.0037	0.0002	0.1546
Chromium	0.2014	0.0014	0.0006

Experiments with nitric acid, however, disclose the fact that this reagent encourages and induces the passive film and that the chromium content facilitates the procedure.

The essential elements with which we are concerned are iron, chromium, and nickel, and it is of interest to study their respective behaviour upon immersion in nitric, sulphuric, and hydrochloric acids at room temperatures. It will be seen by reference to Table 2 that the essential features are the excellent resistance of chromium to nitric acid and the resistance of nickel to sulphuric acid.

THE INSTITUTION OF PRODUCTION ENGINEERS

Table 3 deals with a series of steels in which the nickel content is increased from 5 to 45%. We find that the whole series is readily attacked by nitric acid, the degree of attack being practically unaffected by the nickel content. The resistance to sulphuric acid increases with the nickel, the steel becoming practically resistant to attack by 10% sulphuric acid at room temperatures with a nickel content of 25%. The resistance to hydrochloric acid is also increased.

TABLE 3

EFFECT OF NICKEL ON RESISTANCE TO ACIDS								
(Loss in grams/sq. cm.)								
C %	Si %	Mn %	Ni %	Cr %	Brinell Hardness Number	Hydrochloric Acid, Concentrated	Nitric Acid, Sp. Gr. 1.20	Sulphuric Acid, 10%
0.26	0.16	0.41	4.82	nil.	187	0.1142	0.7388	0.0221
0.16	0.41	0.33	6.05	"	157	0.0872	0.4475	0.0072
0.30	0.13	0.31	9.02	"	276	0.1593	0.6494	0.0102
0.23	0.11	0.18	12.23	"	345	0.1939	0.7123	0.0074
0.32	0.12	0.28	14.90	"	330	0.0816	0.7026	0.0028
0.26	0.12	0.31	20.08	"	198	0.0838	0.6887	0.0010
0.31	0.34	0.98	24.21	"	168	0.0568	0.7532	0.0008
0.18	—	1.00	26.10	"	175	0.0678	0.5914	0.0006
0.18	0.25	1.07	29.30	"	186	0.0290	0.7745	0.0005
0.23	0.12	0.35	36.50	"	157	0.0237	0.5730	0.0003
0.29	0.22	0.57	44.75	"	117	0.0329	0.5684	0.0004

TABLE 4

EFFECT OF CHROMIUM ON RESISTANCE TO ACIDS								
(Loss in grams/sq. cm.)								
C %	Si %	Mn %	Ni %	Cr %	Brinell Hardness Number	Hydrochloric Acid, Concentrated	Nitric Acid, Sp. Gr. 1.20	Sulphuric Acid, 10%
0.39	0.19	0.66	0.41	nil.	167	0.1812	0.5858	0.1032
0.38	0.09	0.18	0.10	5.10	157	0.3075	0.8989	0.2198
0.64	0.19	0.34	0.15	8.96	180	0.1666	0.0005	0.3048
0.29	0.14	0.22	0.09	10.06	180	0.1492	0.0001	0.2143
0.56	0.12	0.21	0.10	12.47	209	0.1845	nil.	0.2496
0.50	0.28	0.35	0.11	15.6	255	0.2902	"	0.4279
0.49	0.23	0.21	0.14	19.66	223	0.1709	"	0.3530
0.53	0.38	0.30	0.10	24.22	209	0.2836	"	0.4543
0.58	0.49	0.31	0.15	32.07	216	0.3221	"	0.5583

The influence of increasing chromium content on the corrosion resistance of the chromium iron alloys is shown in Table 4. Initially the chromium renders the steel more liable to attack by nitric acid but when the chromium content reaches 10% the alloy becomes almost completely resistant to this acid, although the solubility in both sulphuric and hydrochloric acids is increased.

A study of the response of a series of alloys containing both chromium and nickel in varying proportions now becomes of great

STAINLESS STEELS

interest. Table 5 gives data of experiments carried out on a series of steels with chromium contents of 5, 10, 12, and 20%, the nickel content being varied throughout a fairly wide range at each particular chromium content.

TABLE 5

EFFECT OF CHROMIUM AND NICKEL ON RESISTANCE TO ACIDS
(Loss in grams/sq. cm.)

C %	Si %	Mn %	Ni %	Cr %	Hydrochloric Acid, Concentrated	Nitric Acid, Sp. Gr. 1.20	Sulphuric Acid, 10%
0.36	0.05	0.18	0.10	5.06	0.3075	0.8989	0.2198
0.36	0.05	0.13	0.44	5.06	0.1763	0.0003	0.0720
0.35	0.03	0.16	10.39	5.13	0.1897	0.0059	0.1329
0.30	0.07	0.14	15.27	4.90	0.0963	0.0001	0.0015
0.36	0.16	0.20	20.02	5.05	0.0367	0.0002	0.0008
0.29	0.14	0.22	0.09	10.06	0.1492	0.0001	0.2143
0.31	—	0.36	4.88	9.84	0.1732	0.0001	0.0689
0.56	0.12	0.21	0.10	12.47	0.1845	nil.	0.2496
0.51	0.12	0.17	5.23	11.81	0.1479	"	0.1321
1.07	0.09	0.44	0.13	12.26	0.1869	0.0004	0.3565
1.16	0.14	0.39	5.33	12.84	0.1747	0.0001	0.2288
1.07	0.24	0.32	10.33	12.04	0.1483	0.0002	0.1444
0.49	0.29	0.21	0.14	19.66	0.1700	nil.	0.3530
0.52	0.29	0.31	5.40	18.45	0.1664	"	0.2825
0.44	0.33	0.31	15.15	19.16	0.0968	"	0.0015
1.04	0.14	0.21	0.22	20.08	0.2615	0.0001	0.2904
1.09	0.28	0.19	5.44	19.48	0.2826	nil.	0.1311
1.01	0.28	0.17	14.90	19.21	0.0904	"	0.0016

Generally speaking, it will be seen that as regards resistance to nitric acid, the presence of nickel is additive to the influence of the chromium in increasing the resistance to the acid. Moreover, whilst chromium by itself increases the solubility in both hydrochloric and sulphuric acid, the presence of nickel leads to an increased resistance to these acids.

These data give an indication of the fundamental effect of varying the proportion of the different elements, from which have been developed the 18/8 and the 12/12 types of steel, whilst the 15/11 type was devised by another firm working in the same field. All these compositions are interesting owing to the fact that by critical balance they modify the solution of the steels in these different acids.

I now come to a very interesting aspect of the problem. We are frequently asked: "Does this particular steel resist this particular acid?" It is impossible to reply definitely without knowing the precise working conditions, as for example the concentration and temperature of the acid. This fact is clearly brought out by the data given in the following table:—

THE INSTITUTION OF PRODUCTION ENGINEERS

TABLE 6

18% CHROMIUM, 8% NICKEL STEEL (Fully Softened) v. SUPHURIC ACID
AT VARIOUS CONCENTRATIONS AND TEMPERATURES
(Loss in grams/sq. cm.)

Acid %	Temperature					B.P.
	Std. x 20°C.	20°C.	40°C.	60°C.	80°C.	
95.6	5.15	.0017	.0015	.0029	.0041	—
80.	4.04	.0047	.0331	.0353	.1020	.7795
65.	2.95	.0153	.0715	.1620	.3478	1.1216
50.	2.05	.0820	.3430	.4090	.3996	.4860
35.	1.30	.0541	.1468	.1721	.1170	.6310
20.	0.670	.0181	.0594	.1228	.2342	.5680
10.	0.312	.0021	.0221	.0491	.1365	.2394
5.	0.152	.0027	.0177	.0297	.0790	.1343
2.5	0.0741	.0010	.0057	.0147	.0466	.0622
1.	0.0293	.0004	.0026	.0042	0.129	.0271
0.5	0.0146	.0001	.0015	.0029	.0056	max.
0.25	0.0073	.0000	.0001	.0013	.0032	max.

x Gives maximum loss/sq. cm. calculated for pure iron cylinder, area 15.5 sq. cm.

The double lines indicate satisfactory resistance, the single lines fair resistance, whilst those values which are not underlined are classed as unresistant. The fact must be emphasised that in considering corrosion problems the effects of temperature, concentration, and pressure are most important and must be fully known before material can be recommended for any particular purpose.

The data given in Table 7 will illustrate the value of the additions of certain other special alloying elements.

TABLE 7

COMPARATIVE CORROSION RESISTANCE IN ACIDS
(Twenty-four hour tests; loss in grams/sq. cm.)

Reagent	Temp.	Type of Steel		
		14% Cr	18/8 (Cr-Ni)	18/8/2.5 (Cr-Ni-Mo)
5% acetic acid ...	b.p.	Attacked...	Unaffected ...	Unaffected
B.P. acetic acid ...	b.p.	Severely attacked	Attacked ...	Practically unaffected
Glacial acetic acid ...	b.p.	Severely attacked	Attacked ...	Slight attack
10% formic acid...	60°C.	Attacked...	Unaffected ...	Unaffected
80% formic acid...	60°C.	Severely attacked	Attacked ...	Unaffected
1% lactic acid ...	b.p.	Severely attacked	Attacked ...	Unaffected
10% oxalic acid ...	70°C	Severely attacked	Some attack	Unaffected
0.5% sulphuric acid ...	20°C.	Severely attacked	Slight attack	Unaffected.
5% sulphuric acid ...	20°C.	Severely attacked	Attacked ...	Practically unaffected
1% sulphuric acid ...	40°C.	Severely attacked	Attacked ...	Practically unaffected

Here are seen the results of corrosion tests performed on the 14% chromium steel, the 18/8 steel and the 18/8 steel to which 2.5% of molybdenum has been added. Taking for example the case of boiling lactic acid, the 14% chromium steel is severely attacked, the 18/8 steel somewhat less severely attacked, whilst the 18/8 with the molybdenum addition is completely unaffected. This will be found to apply to a vast number of corroding media and over a wide range of compositions. If the research laboratories are supplied with full information as regards composition, concentration, pressure, and other working conditions, in all probability they will be able to provide a steel of suitable composition which will possess satisfactory resistance to the specified conditions.

When metals of different kinds are in contact and any liquid which can serve as an electrolyte is present, conditions are obtained which can cause electrolytic corrosion. Owing to the different solution pressures of the two metals, electric potentials similar to those operating in an ordinary voltaic cell exist, and one of the metals is liable to be attacked.

Some experimental work on this subject carried out in our laboratories will be of interest. Couples were made by forming a thread on the end of a cylindrical sample of one material and screwing it into a threaded hole of a cylinder of another material. The various combinations were examined for their behaviour in sea water. Materials used included ordinary steels, stainless steels of various types, copper and copper alloys, bearing metals, duralumin, solders, etc. The method of suspension avoided contact with the glass containing vessels. In each case the sea water used for a test was entirely replaced every seven days, the tests being continued for twelve weeks at normal temperatures.

It was found that contact of stainless steels and mild steel produced no corrosion of the stainless steels, but a slight increase in the corrosion of the mild steel, the increased attack on the mild steel being more marked in contact with the steels of greatest corrosion resisting properties. Copper and phosphor-bronze in contact caused increased corrosion of the mild steel and the 13% chromium stainless steel, the copper and phosphor-bronze themselves being protected, but in contact with 18/2 and 18/8 chromium-nickel steels, no appreciable electrolytic effect was produced. Increased attack on the 13% chromium stainless steel was also induced by contact with silver solders and copper-nickel alloys. Duralumin was found to be considerably protected by contact with mild steel, but in contact with the stainless steels the effect was not marked either way. Contact of one kind of stainless steel with another, e.g., 18/8 chromium-nickel steel with 13% chromium steel caused appreciable increase in corrosion of the latter. A similar effect was obtained with 18/2 chromium nickel steel in contact with 13% chromium

steel. Steels of the 18/2 and 18/8 type in contact showed practically no effect.

Fig. 2 is indicative of the difference in the characteristics of the various types of stainless steels as revealed by heating and cooling curves. It will be seen from the curves that, in the case of the "Staybrite" steels, critical points are absent and hence the austenitic character of these steels, resulting in the fact that these steels cannot be hardened by heat-treatment. In order to completely soften the 18/8 steels they should be heated to 1050-1150°C. and cooled quickly whilst the 12/12 steels may be softened by heating to 950-1050°C. and cooling quickly.

As regards the plain chromium stainless iron and stainless steels, as well as the 18/2 steel, these have well-defined change points and thus are all susceptible to hardening and tempering treatments.

Stainless irons are generally used in the soft condition and, after either hot working or cold working, may be softened by reheating to about 750°C. and cooling in air. Stainless steel containing about 0.30% carbon and 12-14% chromium, is softened, in a similar manner to stainless iron, whereas it is fully hardened by quenching in oil or water from 930-980°C. After hardening, stainless steel may be tempered to any desired degree depending upon the function and mechanical properties required.

As regards the 18/2 type of stainless steel, this may be softened by heating to 600-650°C. and cooling in air, although it is generally finally hardened in oil at about 960°C. and tempered at 500-600°C.

Table 8 gives representative values for the various types of steel under discussion. You will agree that the range of alloys described makes it possible to have any mechanical properties which can reasonably be desired in steels of a rustless nature. In the 12/12 austenitic steel with a yield point as low as 14 tons per sq. in., maximum stress 35 tons per sq. in., an elongation of 60%, a reduction of area of 60%, and a Brinell hardness of 130/150, one has a very plastic and ductile material, whilst with the 18/2 type in the hardened and tempered condition, a tensile strength of 50/60 tons per sq. in. with an elongation of 25% and a reduction of area of 60% can be readily obtained. If a really hard condition is desired, the 13% chromium steel, hardened and lightly tempered, gives a Brinell hardness of 450/550.

Fig. 3 shows the rate of expansion with increasing temperature—as determined for the different alloys. Referring to "Permant," the steel in which the coefficient of expansion is practically nil, we all know that the extremely low rate of expansion applies only in that range of temperatures not far removed from atmospheric. When the range of temperature applied is in excess of 250°C. this

STAINLESS STEELS

TABLE 8.

MECHANICAL PROPERTIES OF FIRTH RUSTLESS AND ACID-RESISTING STEELS

Description	Condition	Mechanical Properties			
		Yield Point, tons/sq. in. (0.5% proof stress)	Maximum Stress tons/sq.in.	Elongation %	Reduction of Area %
FIRTH-VICKERS STAINLESS STEEL F.I. (Low Carbon, 12/14% Chromium)	Forged and rolled material. Hardened and tempered ...	18/25	30/37	40/30	60/50
FIRTH-VICKERS STAINLESS STEEL F.G. (Medium Carbon, 12/14% Chromium)	Forged and rolled material. Hardened and tempered ... Castings. Hardened and tempered	23/35 20/25	40/50 40/45	30/20 20/18	60/50 50/40
FIRTH-VICKERS STAINLESS STEEL F.H. (Medium Carbon, 12/14% Chromium)	Forged material. Hardened and tempered		100		
FIRTH-VICKERS STAINLESS S.80 STEEL (20% Chromium, 2% Nickel)	Forged and rolled material. hardened and tempered ... Castings. Hardened and tempered	40/50 22/28	50/60 40/50	25/15 18/15	60/45 50/40
FIRTH-VICKERS "STAYBRITE" F.S.T. STEEL (18% Chromium, 8% Nickel, with alloys)	Forged and rolled material. Fully softened Castings. Fully softened	15/18 12/18	37/45 28/34	60/40 50/20	60/40 60/30
FIRTH-VICKERS "STAYBRITE" D.D.Q. STEEL (12-13% Chromium, 12-13% Nickel. Deep drawing quality.)	Forged and rolled material. Fully softened	14/17	35/40	60/40	60/40
FIRTH-VICKERS "STAYBRITE" F.M.B. STEEL (18% Chromium, 8% Nickel, with alloys)	Forged and rolled material. Fully softened Castings. Fully softened	19/19 13/17	40/50 28/34	50/35 40/20	60/40 40/20
FIRTH-VICKERS "STAYBRITE" F.D.P. STEEL (18% Chromium, 8% Nickel, with alloys. For welding without subsequent heat-treatment)	Forged and rolled material. Fully softened Castings. Fully softened	16/19 13/17	40/50 28/34	50/35 40/20	60/40 40/20

steel conforms in general to a similar rate of expansion to that of the ordinary steels.

A study of Figs. 4 to 6 will show the difference in structure resulting from correct and incorrect treatments of the stainless cutlery type of steel.

It is interesting to note the variations in structure obtained in the austenitic stainless steels in the cast, annealed, and forged or rolled conditions (see Figs. 7 to 9). The 13% chromium steel, when heated above the change point to the temperature where the solid solution exists and then quenched, assumes a hardness associated with hardened steel, but when the chromium content is raised from 13% to 18%, together with an addition of 8% of nickel we have a composition which results in the solid solution produced at the high temperatures being retained at ordinary temperatures. It will be remembered that there are no critical points in the austenitic steels (Fig. 2) and hence no change in the type of structure occurs during cooling.

In the early days of these austenitic nickel-chromium rustless steels a good deal was heard of intercrystalline corrosion, and if in the 18/8 class of steel the carbon content was rather high, and the rate of cooling slow, or if after softening the steel was submitted to a red heat, then the carbides in solution were deposited along the grain boundaries and, when subject to certain corroding media, attack was found between the crystals. The seriousness of this is disclosed in the test-piece, shown in Fig. 10. It will be seen that after immersion in a corrosive acid this steel cracked on bending.

Fig. 11 shows the nature of this intercrystalline attack as seen under the microscope. These occurrences belonged to some six or seven years ago, but since those days it has been determined by research that if the carbon is kept below a certain value, or if tungsten and titanium are added to the austenitic steels, then the material is immune from this phenomenon. Modern practice is governed by this fact.

The next few illustrations are included to give an idea of the type of plant involved in the production of these steels. The melting furnaces may be of the electric arc or high frequency type. The former is employed for large casts up to 30 tons and the latter for small charges (Figs. 12 and 13).

In Fig. 14 illustrating the casting of ingots from the ladle, note will be made of the refractory lined feeder head at the top of the ingot which maintains the liquid molten in the upper portion of the ingot until after it is frozen in the lower portion, allowing the liquid metal to filter down and thus ensuring a solid ingot.

Various stages of the rolling operations in the production of plates and sheets are shown in Figs. 15 to 17.

STAINLESS STEELS

A few large scale applications of these steels in the industrial world will now be of interest: Figs. 18 to 22 show examples of "Staybrite" steel vessels used in the food and chemical industries and of stainless steel castings used in hydraulic power plant.

Fig. 23 illustrates the greatest achievement of my industrial life, when I, along with the engineers of the Imperial Chemical Industries, Ltd., were responsible for the selection of the austenitic materials for the construction of their new nitric acid plant in 1926. The whole thing has been the source of gratification to both the Imperial Chemical Industries, Ltd. and ourselves, although you will realise at the time it meant considerable scientific pioneering on both sides.

Some notes on practical questions arising in the manipulation of the steels will be found as an appendix at the end of the published lecture.

The subject is so big that I shall be forgiven for having talked at such great length. The main object I had this evening was to discuss the history and the characteristics of the range of stainless steels now available. There is a wonderful future before them.

At the close of his address, Dr. Hatfield presented to the chairman a tankard made in "Staybrite" steel.

APPENDIX.

SOME NOTES ON THE MANIPULATION OF STAINLESS STEELS.

Hot Working.

For hot working the plain chromium (hardening types) of stainless steel, they should be carefully heated to about 1100-1150°C., the hot deformation being carried out quickly and not being continued below about 900°C. Cooling, after forging, should be carried out slowly and uniformly, bearing in mind that these steels are liable to air-hardening if cooled at all rapidly. As regards the chromium-nickel (non-hardening) types, these may be heated for forging up to about 1,200°C., and although these steels do not suffer from any tendency to air-hardening, on cooling down it is not usually advisable to attempt much work at a temperature below about 900°C. For the purpose of hot forming operations, such as hot pressing, in the case of the chromium-nickel steels it is usual to commence at a temperature of 1100-1150°C.

Cold Working.

Cold pressing, forming, drawing, and spinning : The low carbon variety of plain chromium stainless steel (commonly called stainless iron) lends itself well to cold working operations, whereas the chromium-nickel austenitic steels, owing to their extreme ductility and malleability, are ideal for this type of work. The 12/12 variety in particular (referred to in connection with the production of spoons and forks) is very adaptable to cold working operations and for this reason, this quality is used extensively for domestic hollow-ware, mouldings, spun reflectors, etc.

In such operations as cold pressing and spinning, it should be appreciated that, like all metals, these chromium-nickel steels work harden under cold work so that, for very deep pressings or spinnings, it may be necessary to give one or more intermediate softening treatments (followed by pickling). Furthermore, as in the case of other metals, it is not advisable to leave cold pressed or spun articles in chromium-nickel stainless steel, or in plain chromium stainless iron, in a very highly stressed condition (resulting from an appreciable amount of cold work). Such articles left in a state of severe internal stress are liable to crack in time ; this can be obviated by softening the articles after the last cold working operation, when such an operation has been drastic.

Welding.

Generally speaking, it is not advisable to attempt welding the plain chromium stainless steels, but the chromium-nickel austenitic steels can be readily welded by all processes except that of the smith's hearth.

With regard to the oxy-acetylene method, in particular (since this is more susceptible to the human element than other methods) probably the most essential feature conducive to successful welding, is careful control of the welding flame. It is important that a neutral flame be used. If too much oxygen is present, there is a tendency for the weld to be unsound. On the other hand, if an excess of acetylene is used there is a possibility of the weld being lacking in ductility (and probably also in corrosion resistance) due to carburisation from the acetylene.

In this connection, it would be well to mention that, whereas in the case of some of the austenitic chromium-nickel steels, it is necessary to heat-treat after welding in order to obviate the possibility of the occurrence of what is known as "weld decay" or "intercrystalline corrosion," such precaution is not necessary with the 18/8 chromium-nickel steel containing an addition of tungsten and titanium. In the case of the 18/8 chromium-nickel steel containing tungsten and titanium, the use of a flux is desirable when gas welding.

Soldering and Brazing.

These steels can be readily soft soldered, using as a flux either a 50% solution of ortho-phosphoric acid, or a saturated solution of zinc chloride in a 50% solution of hydrochloric acid.

As regards silver soldering, the most suitable flux has been found to be a mixture of equal parts of potassium fluoride and boracic acid, whereas for brazing a suitable flux is either ground borax glass, or a proprietary flux known as Sifbronze.

Descaling.

The austenitic chromium-nickel steels are readily descaled in a solution composed of 50 parts hydrochloric acid, 50 parts water, and 5 parts nitric acid, to which is usually added about 0.2% of the total volume of a suitable restrainer. The solution should be used warm, at a temperature of 50-60°C.

In the case of the plain chromium stainless steels, it is preferable to loosen the scale or oxide mechanically, say by sand-blasting or "rumbling," prior to immersion in the acid bath, mentioned above.

Machining Operations.

Space considerations permit only a brief statement on a limited number of machining operations and it is hoped that this will be

sufficiently indicative of the general principles. Fuller details have been given elsewhere.

Machining operations must necessarily vary widely according to the nature, form, and size of the job. It is necessary to take into account the different classes of steel and different types of machining operations and also the degree of springiness of the article being machined when subjected to tool pressures.

The best conditions of cuts, feeds and speeds, and tool angles are naturally affected by all these factors and hence a complete programme cannot be laid down. To a large degree each job must be considered on its own merits and slight adjustments made, according to the response the work is found to give to the conditions tried. It should be emphasised that to obtain best cutting conditions, machines and tools should be rigid and free from play arising from worn parts. The nature of the finish given to the job also demands consideration and may necessitate adjustment of the cutting conditions. The accompanying data, representing deductions from a wide range of experimental work, are to be taken as a guide only and do not claim to represent the optimum conditions for any particular piece of work. The final decision as to the best practice in each case must be made by the machinist or man in charge.

The conditions described are intended to relate to ordinary machine shop operations on usual production work. The tools employed for testing purposes are in all cases high speed steel tools of good quality, hardened and ground according to recognised practice.

These remarks apply to turning tools, drills, including centre drills, and hacksaws. Ordinary hacksaw blades are of little use on these materials. For tapping, high class carbon steel taps should be used preferably with ground threads. For shearing operations, one of the special shear blade steels such as those having red hard qualities will be found suitable. For rough turning work, reference is made to two types of tool: form B employed for relatively deep cuts, cutting mainly on the side of the tool, and form A for lighter cuts, cutting mainly on the front of the tool. The section of tool employed is 1 in. square for the smaller work, and 1 in. \times 1½ in. for heavier work.

In screw cutting, cleanliness of cutting becomes an important factor. Perfect sharpness of the edge of the tool must always be maintained.

In drilling operations, to secure rigidity, it is desirable that the drill should be as short as can be conveniently used. In the case of small diameters particularly, the drill should be gripped as low as possible to reduce the springing.

Cutting lips should be ground with rather more than the usual back clearance and the point should be "thinned." All spindle

STAINLESS STEELS

"play" should be eliminated. It is preferable to use a lubricant for drilling. The ordinary lubricant is satisfactory on larger work, but for very small work turpentine is best. Rotation of the drill producing rubbing without cutting should be avoided.

Rough Turning.

Typical cases for machining the 40 to 50 tons per sq. in. tensile condition of the 12-14% chromium steels are quoted under "G" in Table 1. For the 55 to 60 tons condition speeds are with advantage reduced about 20%. "I" related to a sample of stainless iron. Under "S" in the same table are quoted typical conditions for softened "Staybrite."

TABLE 1

Dia.	Typical Speed ft./min.	Cut inches	Feed inches	Type of Tool	Rake Angles		Clearance	
					Front	Side	Front	Side
G.								
1"	70	1/32	1/48	A.	10°	7°	5°	5°
2"	55	1/8	1/64	A.	13°	13°	10°	8°
3"	45	1/4	1/48	B.	7°	15°	4°	5°
5"	35	1/4	1/48	B.	7°	20°	4°	5°
13"	33	5/16	1/48	B.	7°	24°	3°	3°
I.								
1"	110	1/8	1/48		15°	10°	5°	5°
S.								
1"	70.6	1/16	1/48	A.	10°	7°	5°	5°
1 1/2"	52.2	1/16	1/48	A.	10°	7°	5°	5°
1 1/4"	38	1/16	1/48	B.	10°	15°	4°	5°
2"	23	3/32	1/64	A.	13°	13°	10°	8°
4 1/2"	24	3/16	1/40	B.	17°	16°	3°	3°
5"	32	3/16	1/32	B.	17°	16°	3°	3°
6"	30	1/4	1/48	B.	7°	20°	2°	5°
18"†	40	3/32	1/75	B.	5°	15°	3°	5°

* These trials were on material in a slightly harder condition.

† Trials on castings.

Typical data for finish turning are given in Table 2.

Finish Turning.

TABLE 2

Dia.	Typical Speed ft./min.	Cut inches	Feed inches	Type of Tool	Rake Angles		Clearance	
					Front	Side	Front	Side
G.								
1"	100	.0025	1/36	—	15°	0°	7°	5°
2 1/4"	105	.004	1/8	—	20°	0°	12°	7°
I.								
1"	150	.003	1/48	—	15°	10°	6°	5°
S.								
1"	86	1/36	.002	—	9°	0°	7°	5°
1"	64	1/48	.002	—	9°	0°	7°	5°
6"	80	.005	.006	—	10°	25°	3°	3°

Screw Cutting.

TABLE 3

	Speed ft./min.	Depth of cut inches	No. of Cuts	Rake Angles		Clearance	
				Front	Side	Front	Side
G.							
1" diameter V. thread, eight per inch	70	—	12	10°	0°	10°	1°
1" diameter square thread, four per inch	37	.003 .007	—	10°	0°	5°	1°
2½" diameter V. thread, eight per inch. (Finished at 100 ft. per minute) ...	46	.004	—	8°	0°	15°	1°
2½" diameter square thread, four per inch. (Finished at 80/90 ft. per minute) ...	46	.004	—	8°	0°	12°	1°

I.—High speeds, up to 150 ft./min., may again be used to advantage for V threads. A rake angle of 10° with a clearance of 5° was satisfactorily used at this speed. For square threads a speed of 50 ft./min., with similar rake and clearance, gave a good thread. Diehead and machine screwing offer no serious difficulties.

S.—For V thread cutting, the recommended tool is one having 8/10° top rake, with a suitable front clearance angle of 10/15°. Cutting speeds up to 30/50 ft./min. with cuts of the order of 4/7 thousandths, give a satisfactory thread with a good surface, the higher speeds being best for finishing. No lubricant is necessary.

For drilling, typical speeds and feeds for a number of sizes are given in Table 4.

Drilling.

TABLE 4

Diameter	Stainless Steel		" Staybrite " steel	
	R.P.M.	Feed per Rev.	R.P.M.	Feed per Rev.
1/16"	2,050	—	1,200	—
1/8"	1,450	—	850	—
1/4"	830	.0045	460	.0045
1/2"	400	.007	260	.007
13/16"	225	.0095	200	.0095
1"	185	.011	170	.011
	Drill tip clearance angle 8/10°		Drill tip clearance angle 14/18°	

Cold Sawing.

Times of sawing, using high-speed hacksaws on a machine of 6 in. stroke working at 100 to 120 ft./min. (with a copious flow of water), were as follows:—

Diameter	Stainless	" Staybrite "
1"	1½ mins.	2 mins.
2"	6-8 "	10-12 "
3"	15-18 "	25-30 "
4"	25-30 "	35-40 "

Tapping.

For hand tapping of all the types of stainless steels, three flute ground thread hand taps are preferred. The ordinary taps have not the necessary amount of relief and undercut. For best results the tapping hole should be drilled to sizes larger than those employed for ordinary steels, e.g., for $\frac{1}{4}$ in. Whitworth thread with core size 0.186, the drilling size should be 0.202 or approximately $13/64$ in. Space does not permit a full list of drilling sizes but these have been given elsewhere.

The drill should be kept sharp, and care taken on regrinding to ensure correct size of hole. A blunt drill work hardens the surface of the hole, and causes difficulty in the subsequent tapping operation.

The relief on the taps should be from 0.002 to 0.004 in., according to diameter, and the undercut should be from 5-10°.

Too much work should not be put on the taper tap, and immediately it begins to feel hard, the tap should be removed and the second tap started with, afterwards re-using the taper tap if necessary.

It may be necessary to reverse the tap at times to prevent locking and the reversing should be done with care as so to avoid breaking the sharp edge of the tap.

Neatsfoot oil is found to be the best cutting compound for hand tapping.

In special cases where, in order to be pressure tight, a full thread is necessary, then drilling sizes less than those given for general use, but still greater than the core diameters, may be used, leaving only just sufficient allowance for the swelling of the thread in tapping. In such cases the point diameter of the tap should be suitably reduced, to permit of entry into the drilled hole.

THE ORGANISATION OF A MODERN FACTORY PRODUCING PRECISION TOOLS.

*Precis of Paper presented to the Institution, Sheffield
Section, by J. H. Barber, M.I.P.E.*

BEFORE describing the factory which is the subject of this Paper it is not without interest to review, very briefly, the matters which come into consideration before entering into a relatively large capital expenditure of this character.

The first questions asked are—"Will rebuilding pay?" and "If so, what is the likely return on capital expenditure?"

If the same questions are asked concerning the introduction of new equipment they can generally be answered with reasonable accuracy. One has the maker's guarantee or forecast and one probably has the experience of others as a guide but when one considers the effect of a new environment for an existing plant one has no tangible clues to help. Moreover, the resultant economies are mixed up with the suitable rearrangement of the equipment and it will be found that a type of organisation suitable to the old conditions does not fit in with the new. Given suitable organisation and making the most of the advantages resulting from rebuilding the result is a definite reduction in the cost of production. In our case we segregated under one roof several isolated shops; we provided amenable factory conditions; we placed the Stores conveniently and, what is perhaps most important, we arranged that everything and everybody should be exposed to view. This is of prime importance. One can better judge the flow or the accumulation of work; supervision is immensely improved and the tempo of the factory is preserved at the level at which it has been decided that it should be maintained.

For these reasons I have no hesitation in saying that the economies which were confidently anticipated at the time of the inception of this scheme have been justified by results. In no important particular has the scheme, as originally planned, been proved by subsequent working experience to be less satisfactory than was intended.

It goes almost without saying that there is no one type of organisation common to all engineering works. At opposite ends of the scale there are the highly organised mass-production factories devoted to the manufacture of components destined ultimately to

December 2, 1935.

be assembled into a complete machine, and the general engineering works where repetition is the exception rather than the rule.

Plants specialising in the production of tools occupy a place somewhere between these two extremes and, in the particular factory which I propose to discuss, the production of certain types of tools is carried out on a strictly repetition basis, while other items of manufacture necessitate variations from this system to meet clients' particular requirements. It follows, therefore, that plant layout and organisations must take care of both these sets of conditions.

The manufacture of engineers' tools—by which is meant twist drills, reamers, cutters, lathe tools, etc., etc.—involves three principal factors, namely—material, machining, and heat treatment and, consequently, the personnel of the factory must include men who have some acquaintance with metallurgy in so far as it effects ferrous alloys used by the tool maker, both in respect of composition and heat treatment right through from the melting pot to the final tempering. The machining is merely a matter of method.

Most of the existing tool factories in this country have developed from small beginnings and have depended, in their early stages, on the experience of the owner or the individual in immediate charge. In our own case the factory has grown, from its inception in 1903, to a force of more than 450 people. Over that period an organisation has been built up which relieves the factory management of routine responsibility in the design, method of execution, and passage of work through the shops.

With this explanatory note I will now endeavour to indicate the lines on which, in the early part of last year, plans were drawn up for an entirely new factory embodying, so far as practicable, the lessons learnt during thirty years' work in the old one and the manner in which it functions.

The floor area occupied is about 62,000 sq. ft. Provision is made for a loading dock 2 ft. below floor level to facilitate discharge of materials delivered. The dock will accommodate three lorries abreast and serves the raw material stores as well as the shipping stores from which the finished product is dispatched.

To economise space raw material is stored vertically in racks as shown in the accompanying illustration. The various qualities are indicated by different colours and each rack is clearly marked with the size of bar stored therein.

Special machines are employed for cutting this material into blank length and for dealing with the larger bars two circular cold saws, respectively by Clifton & Baird, Ltd., of Johnstone and Noble & Lund, Ltd., of Felling-on-Tyne, both equipped with the "Insto" segmental saw, are used. In addition, there are three hacksawing machines equipped with "Speedicut" high speed steel hacksaw blades.

To ensure a perfectly dry floor over the whole of the factory the datum was raised by hard core filling, finished off with concrete, and finally paved with hard wood blocks, forming a very durable, satisfactory floor.

The main machine shop is divided into six bays running north-west to south-east, with saw-tooth roof. The underside of the long slopes is covered with $\frac{1}{2}$ in. thick Treetex sheeting and painted white, the outside being boarded and covered with two layers of felt with an intermediate layer of bitumen for insulating purposes.

The roof trusses have a span of 29 ft. and are carried on stanchions located at 9 ft. 10 $\frac{1}{2}$ in. centres. The stanchions consist of two 8 in. by 3 in. channels bracketed together and stayed longitudinally with 6 in. by 3 in. I roof valley girders. The bays are bridged by single 12 in. by 6 in. I girders.

The main lines of shafting are carried on ball-bearing pedestals resting on footplates housed between the two stanchion channels, while the countershafts are bolted to the 12 in. by 6 in. bridge girders. By this arrangement a lineshaft with its pulleys is placed in a position and at a height which results in a minimum of interference with the natural lighting from the roof glazing.

As regards the layout of the various bays, it should be explained that each is bisected by an 8 ft. service alleyway running through the centre of the building from south-west to north-east,

It was recognised that the question of artificial illumination of the factory was of paramount importance, particularly during the winter months and, with the system adopted, uniform intensity of illumination of a high order is available in all sections of the factory in which fine work has to be carried out. The main bays in the machine shop are illuminated by 500 watt and 300 watt lamps carried on ball-jointed pendants with conduit suspension. Some of these pendants, of which there are 20 per bay, can be seen in the photograph. The lamps are 20 ft. apart in one direction and 14 ft. in the other and are at a height of 10 ft. 6 in. from the floor. In the inspection department local lights have, by experience, been found to be indispensable and therefore a lighting circuit was run under the floor blocks and brought up through conduit to the back of the benches, each individual lamp being mounted on a telescopic fitting and provided with a metal shade and reflector so that the operator's eyes are protected from the direct rays. Having regard to the special illuminating conditions imposed by the type of work done the pitch of the overhead lamps was halved as compared with that of the main machine shop and the present arrangement seems to satisfactorily meet the case for critical examination of the small and accurate parts which pass through this department.

It may here be noted that the general colour scheme for the structural steelwork is a very pale green with a darker olive green

up to a height of 3 ft. 6 in. The walls are painted the same olive green to a height of 3 ft. 6 in., and white above this.

Atmospheric pollution is a factor which cannot be neglected in an area like the East End of Sheffield and, as circumstances prevented our building the factory elsewhere it was essential to provide a ventilating system which would ensure suitable working conditions and a plentiful supply of clean air. To ensure this an extensive and highly efficient system has been installed whereby the factory is supplied with filtered air on the Plenum system, the air being delivered through adjustable radial diffusers at 108 points in the several bays and maintained at a constant pre-determined temperature. This plant completely changes the air in the factory three times every hour. Working in conjunction with this system there is an auxiliary dust-exhaust system, the dust being drawn from all dry-grinding machines, filtered and returned through the main ventilating ducts.

The Plenum heating and ventilating plant was installed by Messrs. The Standard & Pochin Bros. Ltd., of Leicester. It is designed to maintain an inside temperature of 62°F. with an external temperature as low as 30°F. The main fan has a capacity of 48,200 cub. ft. per minute at a temperature of 120°F.

Except in isolated instances the whole of the machines employing liquid coolant receive their supply from overhead tanks through a distribution system to individual machines, the coolant, after use, finding its way through a system of channels gravitating to underground tanks, from whence it is pumped again to the overhead supply reservoirs. The suds channels are provided with a light covering, flush with the floor, throughout their length, enabling them to be easily cleaned out. There is a small independent coolant system in the material stores for feeding the saws and cutting-up machines in that section.

Reference must be made to the heat treatment department and as the life of the tool depends primarily on the material from which it is made and its correct heat treatment at all stages, this department may be usefully described in some detail. It is worthy of mention that the metallurgist in charge of this department had previously had many years experience in the Brown-Firth Research Laboratory and that the closest possible liaison is maintained between these two sections of the works. The heat treatment shop itself is entirely separate from but closely adjacent to the machine shop. It is extremely well lighted, both naturally and artificially, and particular attention has been paid to ensure that the operators work in comfortable conditions, as in the main block.

The furnaces employed are of the most modern type and consist of a battery supplied with town gas with or without air under pressure, together with electric furnaces, so that heat treatment can be

carried out at all temperatures ranging from those essential for the hardening of high speed steel, approaching melting temperature, down to those required for light tempering operations. The "Selas" gas mixing plant was supplied by the Selas Gas and Engineering Co. Ltd., of Manchester. It has a normal rated mixture capacity of 15,000 cub. ft. of gas and air mixture per hour, with an actual gas capacity of 6,000 cub. ft. per hour. This Selas plant is in duplicate, to permit of extensions when required.

The lecture went on to deal with a number of the manufacturing processes carried out in this factory, including the manufacture of the Firth-Brown "Insto" segmental saw, "Speedicut" twist drills, etc.

Discussion.

MR. WILLIAMS, Section President, who presided : In thanking Mr. Barber for his lecture, the President said that he was sure they had all listened to Mr. Barber's lecture, and seen his slides, with very much interest. Mr. Barber has had an opportunity of doing what I think many of us would like to have the opportunity of doing—being in at the planning of a new factory, and not having to make the best of something that has been bequeathed to you. There are a number of things on the slides that are of great interest. I think the system of ducting his suds and pumping to the tanks is very good. In addition, I was rather struck by his bar racks, and I think one day I would like to pay him the compliment of copying some of these. There was another point of interest, and that was the painting of his factory. Recently, I have been to a good number of big works, and I have been struck by the fact that many people are paying great attention to the painting. The last time I was at the British Thomson-Houston Co. Ltd., for instance, I went into their big machine shops, and they had painted the whole of their machine tools one colour, a light green. No matter what colour the makers had painted the machine tools, they had covered it with this light green. The whole of the columns of the building were painted white, and so were the girders and crabs of the travelling cranes. It had a most striking effect from the point of view of illumination. I think that it is something that will become more and more common in the works in this country. One of the things that Mr. Barber was good enough to show us, was a lathe with a motorised head. I was interested to hear him say that he had no trouble with these machines. I know it is an innovation, but from what I hear about it, trouble seems to have been experienced with the motors. It may do very well, of course, for a certain class of work where you only want speeds within limited ranges, and where you are limited definitely to these three or four changes of speed. They do not give you the same advantages you get with a variable speed motor and the ordinary headstock, but where your range of speeds is limited, you have very definite advantages. There is one question I would like to ask Mr. Barber, and that is, in the early part of his paper, he referred to a routine which they had, which relieved the management of some responsibility in design, and one or two other responsibilities as well. I would like Mr. Barber to enlarge on that, and tell us how it is done.

MR. BARBER : With regard to the colour scheme, I have no hesitation, with my experience, in saying that there is no reason at all if you paint steelwork (I am speaking of an engineering shop as

distinct from a rolling mill), why you should not have the colour scheme as light as you like—white if you like. No matter what colour you paint it, it will get dirty, so you might as well paint it white in the beginning. With this white colour scheme, you certainly get the maximum of reflected light. With regard to the motorised lathe, I think I am right when I say we have no trouble, but of course, we are in the fortunate position of being able to limit the dimensions of the piece very strictly, and consequently three speed changes is ample for our requirements. On the question of relieving the management of routine design. We have made—I suppose most people do—hundreds of standard prints embodying every standard tool we make, or are asked to make, and we have built up an organisation in which everyone is a specialist for dealing with different matters, and quite honestly, matters which I, as manager of the place, would have to deal with individually, I pass on with confidence to other people. It is just a question of specialisation. We deal with fine measurement in some of the tools we make, and the means of effecting this measurement, are left in very competent hands.

MR. WILLIAMS : I think you are fortunate if you can train your people like that. I am sure Mr. Barber would be very glad to answer any questions, or give you further information on points of interest that may have arisen from the lecture. He rather stole some of my thunder. I was going to have a lot to say about the belts.

MR. BARBER : I think we have about 400 machines in that shop. Some of them are rather like sewing machines. They are difficult to motorise.

MR. MARRIOTT : I was interested in what Mr. Barber had to say about twist drills. Knowing the price of twist drills, I can imagine what some of his production times must have to be to make a profit. With regard to fluting, there are two other ways of obtaining flutes, irrespective of milling, and I cannot see myself why they have not been tried. One way is to roll the steel with flutes in and twist it afterwards. I know the morse taper showing is not a pretty picture. The other way of making a twist drill is with forging it with a type of angle that will definitely forge the flutes in. The forged drill, as a drill, seems the best of the lot. If you get an ordinary drill, and mill it, the fibres of the drill are not following the flute. The forged drill seems stronger, and it certainly saves a considerable amount of steel. I know that in the biggest drill works in America they do that, and the Americans claim that the so-called clean forge drill has a greater penetration than the ordinary drill. I know it has been made in this country, so has the twisted one from forged steel. I should like Mr. Barber's views on why it has been turned down.

MR. BARBER : That is very interesting indeed. The idea of forging, of course, makes a natural appeal, and we did, some years ago, forge the drill, but I do not think you are quite right in saying that

all they require is grinding after forging. They require more than that ; they require machining to shape. The shape of the flute has got to be precise, and if you do any grinding on them as we do (we do actually grind them after fluting) you have got to maintain the shape exactly, or the cutting lip would be no longer straight. As far as that goes, the cost of forging, plus the machining to exact shape, would come out probably a little bit more than it costs us to machine them from the solid. There was a German firm who offered us plant for doing what you suggested. I got in contact with various firms who knew more about this apparatus, and they were not at all complimentary about it. The result was we did not adopt it. How far the clean forge drill is in fact forged, I am not prepared to say. Whether there are any advantages in actually forging the shape rather than machining, well, that is in the realm of possibility, but I am not prepared to say whether the resultant tool would be more efficient. I think possibly there is more in the preparation of the steel—the method of forging the steel beforehand, than there is in the preparation of the drill by a process of forging rather than by machining. You see, high speed steel presents difficulties. You cannot make it flow like you can a more ductile material, and therefore, you are driven to get your sharp edges by machining rather than by forging. Some years ago, a Sheffield firm made twisted drills, and they were quite effective, but for some reason the system gave way, and I think the same Company now make them by the same process as we make them. They had a clever idea for twisting a drill from a flat bar, and the shank of the drill was formed by twisting at a quicker rate. I think it may possibly have had disadvantages, anyway, it did not have a very long life. Referring again to the question of forging, the greatest enemy is decarburisation, and you have to be extremely careful that you do not decarburise the surface of the tools, and that means a very careful heating in correct atmosphere.

MR. MARRIOTT : Are the furnaces you use atmosphere-controlled furnaces ?

MR. BARBER : We employ two or three systems, but most of our furnaces are home made, because we were not able to buy exactly what we wanted, and of course the electric furnaces we have, have the gas curtain, which is getting on towards perfection, but is not there yet. Those are problems we are working on now.

MR. WILLIAMS : I suppose the shanks you weld on are flash welded in a special butt welding machine.

MR. BARBER : Yes ; we put in a machine about twenty years ago. After running it for a few months, we scrapped it, and that was a pure resistance welder. It is only just in recent years these people have given us exactly what we want.

MR. WILLIAMS: I certainly think it speaks well for welding, when you can take a shank and weld it on to high speed steel.

MR. EARNSHAW: I have been interested myself in Mr. Barber's remarks to-night, and I should have liked him to have given a little further information with regard to the progress of the work through the shops.

MR. BARBER: I do not think it presents any difficulty. We are able, fortunately, in the majority of our work, to manufacture in batches. We put through a batch under an order number, and the batch of work is accompanied through the works by a tag. In the case of special work, or work requiring special processes or attention, we issue at the same time, an instruction card. The nerve centre of the place is a planning department, who decide on the methods of machining and the general design, and they issue what we call an instruction card, which is made, I think, in triplicate. One is held in the shop superintendent's office, one is recorded in the main office, and one goes through the shops with the work. From that point, there are quite a number of different forms issued. There is a piecework card, which is issued to the man. A man goes to a central office for his batch of work, and it is given to him with a piecework card, on which the rate is laid out, and these cards ultimately form the basis of the cost for the particular job. I do not know if there is any special point you would like explaining.

MR. EARNSHAW: No, I do not think so. I was interested in the method of progress. Are you of the opinion that the straight piecework is the best to-day?

MR. BARBER: I have no doubt, as far as our work is concerned, that the straight piecework is by far the most convenient system to work, and the most effective. We have no trouble at all with our people. Many of the rates, like other of the Sheffield industries, have been arrived at over a period, and they are stable. On special work, we fix the rate, make one or two pieces, make the necessary adjustments, and after that we never alter it. We may, by arrangement with the men when the first two or three pieces are made.

MR. WILLIAMS: I have seen this tag system in operation in quite big works, and I do certainly think that where it can be employed, it certainly is very efficient. This tag contains the whole instructions and moving instructions from one department to another, and it remains with that job throughout its progress in the shops. Of course, not all works are suitable for that kind of thing, but where it can be employed, it is certainly very effective.

MR. BARBER: These light manufacturing plants are similar, I suppose, to a motor factory where a component is issued in quantities, and our problem is not yours. You have to construct a single machine of considerable value, and which consists of a very large number of different parts. We are more concerned with manu-

facturing a component, and we have to be extremely careful, of course, on individual costs, process costs, on that job so that it can support itself. The organisation for a works making large machines is very different from one making, as I say, small parts or components. I was up north not long ago, in the works of a machine tool maker, and he frankly confessed that "the swings had to pay for the roundabouts." He was never sure what a thing would cost him.

MR. WILLIAMS : I am surprised to hear in any well conducted works they should say that. I should think your works should be as simple from a costing point of view as you can have, and from a piecework point of view too. I see no reason (it does not matter how diverse your products), why you cannot be sure of your costs. There are very few people who make the diversity of products that we make, but we can tell you to within a few coppers what each operation will cost. I am rather surprised to hear that machine tool people should say this.

MR. BARBER : It is not so much gathering together the cost after the thing has been accomplished, but the estimating of what the exact cost of manufacturing a special machine tool is likely to be.

MR. WILLIAMS : I agree that is a very different problem and I think that was behind the question when someone asked whether straight piecework was the best to adopt. It is where you can define what a job is likely to cost in the case of machining work, but where you get other operations—foundry, fitting, etc.—I think it is a matter open to debate. I think a system such as the Halsey system, which gives you a wider margin, is probably better from the man's point of view.

MR. BARBER : That is how two systems are bound to vary to a large extent. Even if a motor manufacturer alters his car, it makes a small matter in the machining of his components.

MR. WILLIAMS : It is when you get these "one offs" of unusual jobs that you get into trouble.

MR. COLLINS : I had the privilege of going round Mr. Barber's works some time ago, and I rather wish I had heard his lecture before I went round. I would like to say that I did not actually notice the flow of work through his shops that he emphasised to-night. It seems to me that the heat treatment shop and the sand blast place were rather tucked away in a corner, which one would not consider correct in a straight flow of work, say in the question of drills. It seemed to me that the sand blast shop was well away out of sight. Probably the construction of the building had something to do with that. I was rather interested in his heat treatment shop. I should like to ask him more about what he called his home made furnace, and if he could say something about it, I should be very interested to hear a little more about it, whether it was gas or electric. Also

does he have any trouble with the question of the welding of shanks on to drills. Do they fracture through the weld after heat treatment. I was interested in the mild steel trays he showed. Are these definitely fixed in position, or can they be moved round the works. The question of lighting I thought most interesting. Mr. Barber did not actually say what sort of lights he had placed close to the machines. I fancy that some of the machines are rather intricate, and it is necessary to have the lights very close. As regards manufacture, I notice he showed milling cutters for milling and backing off the drills. I believe some people grind the backing off, instead of the process you showed on the screen. I should like to know something about this. Also, how does he deal with the customer who has ordered special drills that were to be delivered six weeks ago? I notice he said everything went through in batches. I was struck in going through the works, with the cleanliness, and generally very comfortable conditions under which the men worked.

MR. BARBER: We had quite a free hand in positioning the hardening shop and its attendant sand blasting, and we put it where we did with full intention. A hardening shop naturally has rather a complex service of gas, electricity, air, etc. As I have said, we use pre-mixed gas and air, which necessitates an isolated mixing house. We have raw gas, compressed air at 80 lb. low pressure at 3 lb., alternating current and direct current. We have two voltages of alternating current, and direct current is 200 volts. We have a complicated system of plumbing and water mains, and we have an oil circulating system. I am just mentioning this because I want you to understand that they are not the kind of things you can put in a machine shop. Its various services are extensive, and with the collection of spent gases of combustion, it is quite a problem, and you really have the inclination to isolate it from the rest of the factory. In some works, I have seen cyanide furnaces placed in a machine shop, which I consider is entirely wrong. What it means in transport to us, which is very little, is, in my opinion, outweighed by the desirability of isolating a shop of that kind from a machine shop. We go to considerable pains to purify the air supply to the main shop and if we pollute that air, it would undo what it has cost us thousands of pounds to do. With regard to the home-made furnaces. Our most effective furnaces are all home made, and that simply arises out of the requirements of the job. If you make a particular product you look round for the best means of handling it, and we have evolved continuous furnaces for heating. The origin of these was quite simple. We came to the conclusion some years ago that time was just as essential in this heating process as temperature, and whilst we relied on careful workmen, we found occasionally they departed from grace. We regulate these furnaces mechanically, and the duration of time is governed to a second or two. The

steel tables are portable, and can be moved quite easily. There is a definite advantage in having a standard height, standard width, and varying lengths. You can build these things up into anything you want, and you can make it any length you like. With regard to milling versus grinding the backing off. We do both. We mill the larger ones, and we grind the smaller ones. As to the irate customer, like the poor, he is always with us. We have to make what we are asked to make, and sometimes these specials do take a long time to get through. Of course you get the novelty things. Sometimes a customer has his own ideas, and tells you exactly what he wants, without considering how it is to be made.

MR. CATTLEY : In the photographs, I thought the shops looked rather tall or high to the roof in comparison with the small machines that were installed. What was the height of the roof, and why was it fixed at that height ?

MR. BARBER : The shop is 17 ft. to underside of roof trusses. The overhead driving apparatus, from memory, is about 14 ft. You think it is a little high for the type of machines ? There is no crane in that place, the work is of a light nature, and the only cranes used are portable cranes, which are very effective. They are Morris portable cranes, with a lifting capacity of 30 cwt. for lifting heavy jigs, etc. We have not catered for any very heavy lifting at all.

MR. WILLIAMS : That raises one point. I suppose you have got your own tool room staff to look after the maintenance of your own machines and your own special tackle. What about your belting staff ? I imagine you must have somebody to look after that.

MR. BARBER : Yes, we have a fairly complete system of overhaul. We rarely have less than two machines under complete overhaul. It means, of course, that we have to carry a staff of tool maintenance men—tool fitters, who can strip down any machine in a very short time; and they can practically re-build the machines. On many simple processes, reconditioned machines of that character are just as effective as new machines. We employ a number of girls on single purpose machines, and if the machine is kept in good condition, it is just as well as using an expensive machine. In turning the drill blanks, we should not hesitate to put in an automatic machine, whatever its cost, if it is economical to run. We have had grinding experts who tell us we ought to grind our drills from the black bar, by a direct in-feed, which would cover the whole of the body of the drill. It is rather curious how that scheme was defeated. The material we are using is high speed steel, which may cost in the order of 3s. per lb., and we recover from the melting department so much a lb. for the scrap. If you grind the drill, you lose the scrap, and it does not matter how cheaply you grind them, you have lost because of the scrap.

MR. PEARSON : The question of grinding scrap is rather interesting. We tested some grinding scrap, and we found it was possible to recover about 70% from the grinding sumps if you care to do it. We just experimented to see what we could recover magnetically.

MR. BARBER : It did not occur to me that we might recover it for melting purposes. It deposits out in the form of a slime. Whether you could separate it out into pure steel fit for re-melting, and exactly how the melting department would regard what is practically powder, I do not know. They might be able to deal with it, but I am not prepared to say.

MR. PEARSON : I would suggest you use the scrap from the swarf on roads. I have seen it done. It makes a very hard surface. There is one point in the slides which interested me, and that was the belts leading from the counter shaft to the machines. They appeared to be practically vertical. Have you any trouble with slip on these particular machines? It struck me a little angle of inclination would be of advantage. Probably it is the way the slides were taken, but it gives one that impression. With regard to the irate customer, I heard of a manager of a firm saying to a Sheffield tradesman, "Your materials must be good, because apparently you do not want to part with them."

MR. BARBER : We shall have to experiment with the swarf in the manner you suggest. I remember in the file department, we had, some years ago, what I think they called a "Swarf Club," or something like that. Anyhow, we allowed the men to take possession of the grinding wheel swarf, and I believe they made quite a nice bit of pocket money out of it. What it was used for, I do not know.

MR. PEARSON : In the Redditch district, the swarf taken from the needles, which is steel and grinding dust, is used on a road. There is a road there that has been made with that swarf, and it has a very fine surface indeed. When I heard about it, I thought it was a "leg pull," but they have found out over a period of time, that it is a very good medium for a hard wearing road. It is crossed so that people will not fall down, and when I walked over it, it was particularly hard, and free from pit holes.

A cordial vote of thanks to the lecturer, proposed by Mr. Marriott, was adopted.

COVENTRY GRADUATE SECTION.

Foundation Meeting and Presentation of Gift to the new Technical College.

MR. H. A. DRANE, President, Coventry Section, presided over a numerous gathering of members and friends held at the Technical College, Coventry, to consider the formation of a Coventry Graduate Section.

The occasion was availed of to make a presentation of a gift to the new Technical College from the Coventry Section.

MR. J. A. HANNAY, Past Chairman of Council, who was the principal speaker, gave a very interesting survey of the work of the Institution and, in particular, its work on behalf of Graduates and young engineers taking up the profession of production engineering. He explained how necessary it was for the younger men to keep up with the ever-changing methods of manufacture. The 14 senior sections of the Institution were always ready to help in this and to give the younger members the benefit of their knowledge and experience.

It was proposed by MR. A. W. BUCKLAND, Grad.I.P.E., seconded by MR. B. F. T. MEMBERY, Grad.I.P.E., and carried unanimously, that a Coventry Graduate Section be formed.

MR. A. McNAB, Grad.I.P.E., Chairman of the Birmingham Graduate Section, and MR. G. A. WOOD, Grad.I.P.E., Hon. Secretary, spoke of the work being done by their section, which had now over 80 members. They wished the new Coventry Section every success.

THE MAYOR OF COVENTRY, ALDERMAN T. E. FRISWELL, attended the meeting and received from the Section President, MR. DRANE, on behalf of the Coventry Section, the gift to the new Technical College of an "Eclipse Portable Magnetic Chuck," made by Messrs. James Neill & Co. Ltd., Sheffield, to add to the equipment of the College.

THE MAYOR, in thanking the Coventry Section for its gift, said that, while he had little engineering experience of magnetic chucks, he realised how important it was for the students at the new College to have both the knowledge and the use of modern tools. He was pleased to know that many past students of the College were associated with the formation of a Coventry Graduate Section of the Institution of Production Engineers, which he was sure would be a successful and valuable addition to local activities.

THE INSTITUTION OF PRODUCTION ENGINEERS

THE MAYOR handed the gift over to the Principal of the Technical College, MR. D. R. MACLACHLAN, for service in the well-equipped workshops.

MR. J. WILSON, Vice-Principal, also spoke, and during the evening MR. G. CAULTON, M.I.P.E., arranged a very interesting home talkie display, by kindness of the B.T.H. Co.

MR. L. WHITE, Grad.I.P.E., proposed, and MR. A. E. GROOCCOCK, Grad.I.P.E., seconded, a cordial vote of thanks to Mr. Hannay for his address.

The chuck presented to the Technical College, of which an

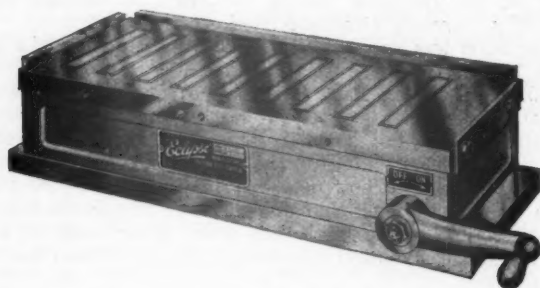


illustration is here given, bore the following inscription: "Presented by the Coventry Section, Institution of Production Engineers, November, 1935."

